Hot Operating Temperature Technology

Development of a TRL6 Electric Motor and Position Sensor for Venus

Completed Technology Project (2017 - 2018)

Project Introduction

Future robotic missions to Venus require actuators for powering robotic arms, sampling systems, and gimbals for the positioning of cameras and antennas. There are many types of actuators (e.g. pneumatic, hydraulic); however electric actuators offer the greatest versatility for space missions. An electric actuator consists of an electric motor and a position sensor. The electric motor converts electrical energy (electricity) into mechanical output (shaft rotation). The position sensor, on the other hand, determines the angular position of the motor shaft, which then is processed by drive electronics to commutate and control the motor. Because of the extreme conditions on the Venus surface (92 bar pressure, 462 °C temperature, and supercritical CO2 atmosphere), conventional actuators will not be able to function properly, or at all. The main challenges pertain to changes in electrical properties like an increase in wire resistance (leading to greater losses), changes in magnetic properties like permeability and retentivity (leading to demagnetization of magnets), and changes in physical properties such as linear expansion, decrease in strength, increase in friction, and accelerated oxidation. Since 2007, Honeybee and NASA Jet Propulsion Laboratory (JPL) have been developing Venus actuator technologies. We developed a 48V Brushless DC motor (BLDC) and custom position sensor called the Pulsed Injection Position Sensor (PIPS) for motor commutation and feedback control. The motor and PIPS are at Technology Readiness Level (TRL) 5. The main objective of the proposed work is to mature the Venus actuator technology through an iterative process of Venus chamber testing of a TRL5 actuator, followed by re-design and fabrication of a TRL6 actuator and subsequent Venus chamber qualification testing of that actuator. The critical objectives to be met are as follows: 1. Design of a motor with 28V windings (28 V is a conventional spacecraft power bus), 2. Increase PIPS resolution from 12 to 48 counts/rev (this will make motor more efficient and allow actuator to be used for precision positioning systems – robotic arms and gimbals), 3. Establish reproducible procedures, standards, and guidelines for fabricating, assembly, test, and inspection of Venus actuators (currently actuators are hand crafted by selected engineers – this knowledge needs to be captured so that any skilled person will be able to fabricate Venus actuator whenever needed). Technical approach: This effort will be achieved in one year period to enable technology infusion into the New Frontiers (NF) Venus In Situ Explorer (VISE) mission. Specific tasks are: Step 1 (Months 1-3): we will characterize performance of the TRL5 actuator under Venus conditions in JPL's Venus Materials Test Facility (VMTF) chamber. We will connect two existing TRL5 BLDC actuators: one will act as a brake to enable characterization of the second actuator. The actuator will be run until failure in order to assess failure condition. Step 2 (Months 4-9): we will incorporate lessons from Step 1 to design and fabricate three 28V actuators. We will develop procedures and standards for fabrication, inspection and testing. Step 3 (Months 10-12): we will perform the same tests as in Step 1 to characterize performance of the 28V actuators. At this point, it is assumed that we will be able to fabricate identical TRL 6 actuators by following manufacturing process developed in

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Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

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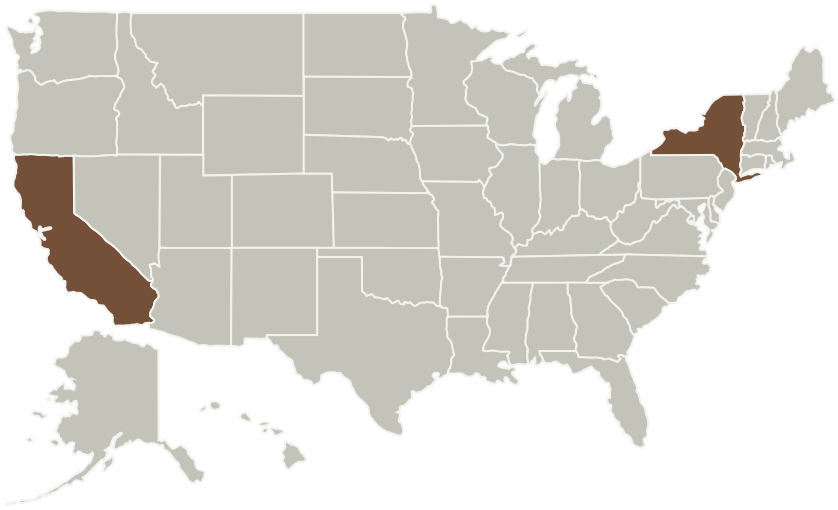
Step 2. Significance of the work to the solicitation: HOTTech supports development of electrical technologies (such as our proposed electric actuator) for the robotic exploration of Venus surfaces. Our electrical actuator will enable Venus missions in the Discovery, New Frontiers (Venus In Situ Explorer), and Flagship (Venus Mobile Explorer) class. Per HOTTech, our actuator also has terrestrial applications in the Geothermal, Oil and Gas, and Aeronautical industries.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Honeybee Robotics, Ltd.	Supporting Organization	Industry	Pasadena, California

Primary U.S. Work Locations	
California	New York

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Quang-viet Nguyen

Principal Investigator:

Kris Zacny

Co-Investigators:

Fredrik L Rehnmark
James E Polk
Chris Chapman
Cody A Hyman
Jeffery L Hall

Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  - TX17.3 Control Technologies
    - TX17.3.4 Control Force/Torque Actuators

Target Destination

Others Inside the Solar System